Resonance in Upconversion Excitation

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Upconversion (UC) processes are discussed on the examples of excited state absorption (ESA) in $LaCl_3$: 1% Er^{3+} for 980 nm excitation and energy transfer upconversion (ETU) in β-$NaYF_4$: 20% Er^{3+} for 1523 nm excitation.

The crucial importance of resonance is demonstrated for one- and two-color excitations in $LaCl_3$:Er, see Fig. 1. For ESA the excitation spectra are convolutions of the individual excitation steps and the UC luminescence intensity shows a linear dependence on the excitation power of each step. For one-color excited ESA and ETU in the low power limit, the exponent of the power dependence is equal to the number of excitation steps. The exponent is reduced due to saturation effects for higher power excitation. The ETU excitation spectra resemble the ground state absorption as shown for β-$NaYF_4$:Er. Upon broad-band excitation by sub-Si-band-gap infrared light β-$NaYF_4$:Er shows UC luminescence mainly from the $^4I_{11/2}$ state around 980 nm which efficiently excites a Si solar cell. This Er UC luminescence due to $^4I_{15/2} \rightarrow {}^4I_{13/2}$ excitation is two orders of magnitude more intense than any UC luminescence of other rare earth ions under the same conditions of broad-band sub-Si-band-gap excitation.

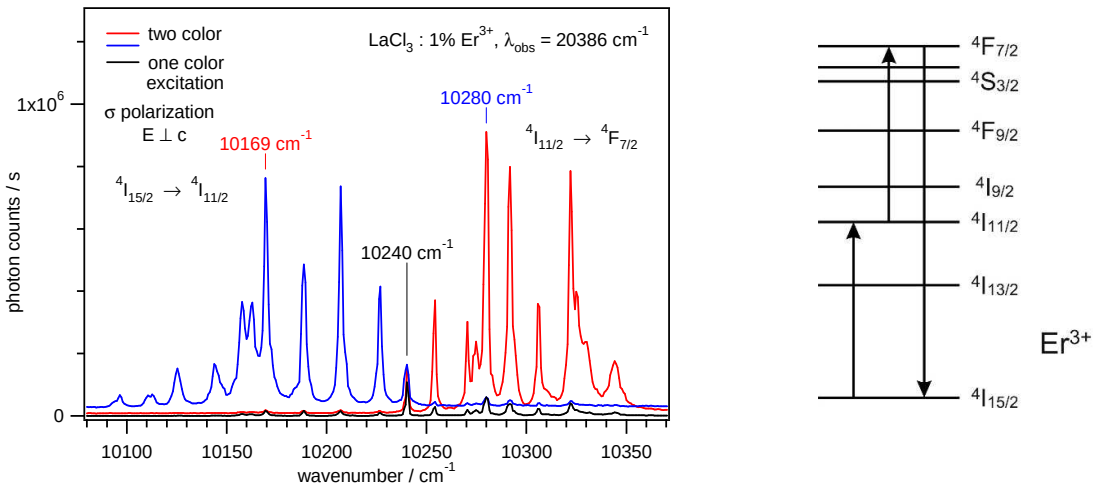

Fig. 1. One- and two-color excitation spectra of $LaCl_3$: 1% Er^{3+} at 78 K for σ-polarization (E⊥c) of the excitation light. The one-color spectrum (black trace) shows a maximum at 10240 cm^{-1}. The two-color spectra (blue and red traces) reveal the overall emission maximum for 10169 cm^{-1} and 10280 cm^{-1} excitation energies.